Teaching A-level Mathematics in Early Career: Report for the Further Mathematics Support Programme.

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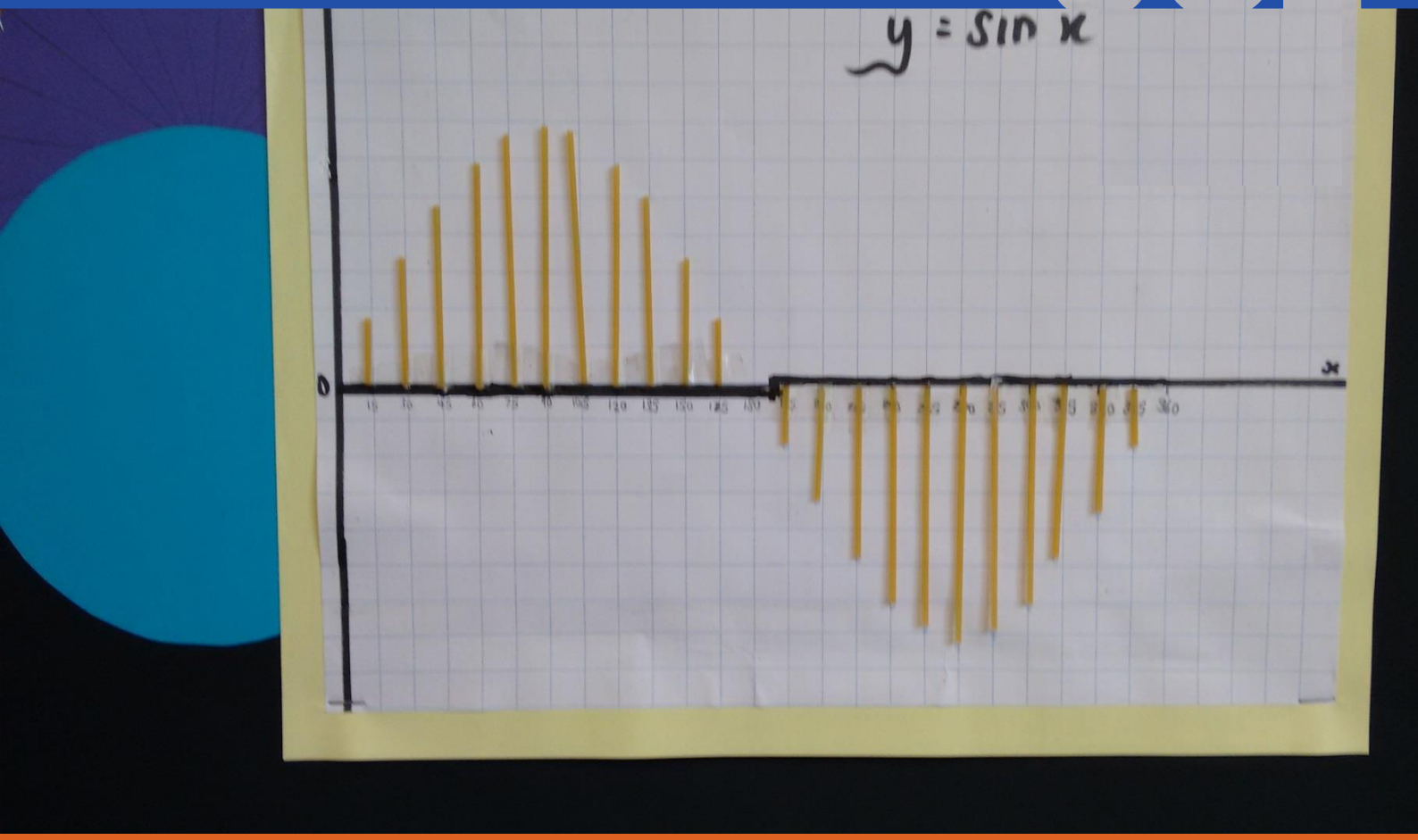

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Cathy Smith and Jennie Golding

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January 2017

Contents

Summary of Findings

1. This study mapped variation in how A-level teaching can develop for well-qualified new teachers, based for their training and induction years in 11-18 schools, and identified where they found support and challenge for improving as teachers. As a result, we conceptualise A-level teaching as complementary to main school teaching and argue that it contributes to the development of teaching repertoires.
2. We found a shared understanding that A-level teaching is a privilege, offered after teachers have shown themselves to be strong in mathematics or confident in teaching, and where responsibility for students can be shared with a more experienced colleague. Early career teachers considered it central to their perception of having arrived as professionals, and A-level opportunities were prominent when choosing a second post.
3. Formal mentor support for NQTs soon reduced and was replaced by informal support conversations with available colleagues. In relation to A-level, support focused on logistics and two key induction messages, and addressed only the immediate concerns/risks faced by new A-level teachers. Teachers regretted the near-absence of reflective conversations focused on A-level pedagogy, which occurred only as a response to perceived deficiencies.
4. Teachers developed some aspects of pedagogic content knowledge from A-level teaching more intensively than in their main school teaching. Smaller amenable classes stimulated and allowed teachers to: focus on feedback from learners; reflect critically on exposition and other approaches to learning; experiment and consolidate routines for management and routines for promoting learning. Engagement with A-level content provoked teachers to: appreciate the 'big curriculum picture' (especially if they were teaching pure mathematics or statistics) and refine teaching goals; consider when and how to introduce rigour; engage with a variety of representations; re-engage as learners; plan and deal flexibly with unusual and unexpected student thinking; differentiate interactions with students, though the depth to which these developed of course varied between teachers.
5. Teaching A-level added to these teachers' workloads during a stressful career stage, and, for some, to their reported anxiety. For this sample, of well-qualified young teachers, the planning demand was mitigated by the relief of a contrasting atmosphere and the satisfaction of professional learning that ensued.
6. For several, teaching materials and approaches introduced in TAM or TFM courses were significant in helping teachers to negotiate the purposes of teaching routines, and manage working in non-procedural ways at this level.
7. A-level teaching impacted on early career teachers' sense of themselves as rounded professionals. A-level teaching was a context that aligned them with their imagined identity as a successful learner-turned-teacher. The focus on pedagogy proved a powerful affective stimulus for sustained effort.
8. For some of these well-qualified teachers, experiences of teaching A-level during early career were critical in retaining them within the education sector.

Background

This research project investigates the place of A-level teaching within mathematics teacher education and development: what induction teachers can expect in early career, and what role A-level plays in their development as teachers. It is not compulsory for teachers to have any pre-service experiences in preparation for teaching A-level. The national Initial Teacher Education (ITE) regulations in England require secondary teachers to be prepared and assessed as competent for only two successive key stages (KS), normally taken as KS3 (11-14 years old) and KS4 (14-16). England offers a variety of routes into teaching, led by schools, universities and other education organisations, all of them requiring a minimum of 28 weeks spent in schools. Higher Education (HE) PGCE courses traditionally provide the most extensive training out of the classroom: providers at our 2016 seminar reported variation in their out-of-classroom sessions focused explicitly on A-level content from none to a full week. Government policy has increasingly promoted an apprenticeship model of teacher preparation, implementing bespoke training run by clusters of schools, or charities such as Teach First. The unqualified teachers on these routes are often salaried, and take nearly a full teaching load during their preparation for qualified teacher status (QTS). Their out-of-classroom training is more limited in time than for trainees on HE-led routes, and fits around the teaching role. Whether and how any of these routes involves any A-level preparation is usually for the school to decide. Schools vary considerably (and regionally) in their post-16 teaching arrangements and it would be impractical for a large ITE provider to *require* A-level experience for their trainees. In practice, schools are usually cautious of giving examination classes to unqualified teachers. The result is that, for all routes, ITE for secondary mathematics is typically focused on the 11-16 age group.

We have found just one published study of how teachers are inducted into post-16 teaching (Butcher, 1999, 2003), reporting on an 11-18 PGCE route (now closed) with subject specialism in English, and suggesting that this area has been under-researched. Butcher concluded that school-based mentoring for post-16 teaching in the QTS year was "invisible", leaving trainees to "sink or swim". He concludes that learning to teach post-16 courses may best be left for the early career stage, assuming a Newly Qualified Teacher (NQT) developmental programme that would support it. Our research takes up this focus but in the context of mathematics, and fifteen years later. In this study, we identified five teachers graduating from three mainstream routes into teaching mathematics, all of whom had been allocated A-level teaching in their NQT year, and followed them over an early career period of 20 months, investigating the questions 'How are early career mathematics teachers inducted into teaching A-level?' and 'What are the effects on their development as teachers?'

The dearth of literature focused on A-level preparation means we have drawn on several related areas to structure our field work, namely teacher career development, teacher knowledge frameworks and teacher learning.

Teacher Career Development

Teaching careers are typically considered to have an early career phase of at least three years during which teachers consolidate their classroom skills and establish their identity as a teacher. There is considerable evidence that novice teachers have different skills from experts. Expert teachers use routines, recognise patterns, deploy a wide range of representations and adapt their teaching more than novices; their expertise depends on knowledge of students' likely reactions to school mathematics tasks, personal relationships and having already established students' expectations for how they will behave and learn. Berliner (2004) quotes evidence to show that all this typically takes between 5-7 years to build – if a teacher deliberately works at it and has

effective mentoring/coaching. This period of a teaching career is usually seen as one of stability, focussed on core teaching and learning, for which A-level teaching might be seen as contributing a more holistic understanding. Certainly, a European approach has been to foster teachers' understanding by focussing on 'big ideas' that have mathematical and pedagogic power across all age ranges. Kuntze et al. (2011) found that pre-service teachers struggle to identify school mathematics topics exemplifying the 'big ideas' of infinity and proof, two themes that they note are particularly relevant to A-level teaching. For us this suggests that making connections between A-level teaching and other mathematics should indeed be considered part of the specialist knowledge gained by teachers, and not simply an extension guaranteed by knowledge of mathematics.

Coldwell, Maxwell and McCaig (2010) contrast this view of early career as classroom-based consolidation with a more active approach of staged career progression towards leadership responsibilities and whole-school awareness. In their survey of senior leaders and early career teachers, some schools protected early career teachers from out-of-classroom responsibilities to develop core teaching while others allocated in-subject planning responsibilities from the NQT+1 year, and encouraged teachers to get the 'bigger picture' by working on whole-school areas such as citizenship. Their findings suggest that early career teachers are themselves adopting a more protean view of career, that is, they are concerned with building up a range of experiences that will allow them to develop individually and move jobs within teaching, rather than becoming experts in a particular school role. A-level teaching may be seen as one such experience.

A particular focus of Coldwell et al's survey was the effect of different organisational strategies on teacher retention. Schools that provided explicit staging of responsibilities for career development were more likely to report that they retained early career teachers than those where responsibilities were either withheld to allow consolidation or given solely in response to school needs. Although retaining teachers is a goal for most schools, there was some resistance to the former approach from senior leaders who feared that early career teachers were seeking responsibilities for which they were not ready and which distracted from the development of their teaching, so acting against their own, and the school's, long-term interests. Although this study did not consider A-level teaching explicitly, its relevance is highlighting the ways that A-level teaching can be viewed as a career stage and, perhaps, differently by teachers and school leaders. If it is considered as part of, or enhancing, the standard teacher role, then induction in early career can be viewed as consolidating teachers' classroom practice. If it considered as an extra responsibility then it may be either withheld protectively by senior staff, or sought by new teachers as symbolic of their progress.

We have more explicit information about early experiences of A-level teaching in England from the longitudinal survey results of the large-scale, all-subject Becoming a Teacher project (Tracey et al., 2008). This found that 49% of secondary respondents were teaching post-16 year groups (either A-level or GCSE resit) by their NQT+1 year, up only slightly from 41% of NQTs, although 92% were teaching a year 11 examination group. Preparation for teaching A-level is thus directly relevant for up to half the cohort in England, and relevant to nearly all the cohort in establishing what Hill, Ball and Schilling (2008) call 'horizon knowledge' of how GCSE mathematics is related to larger mathematical ideas, structures, and principles. Early career teachers cited subject-specific knowledge only as their fourth professional strength (after student relationships, organisational skills and maintaining discipline) and, correspondingly, they cite it as their main professional development (PD) need. 4% of NQTs said they wanted training to teach A-level and 18% wanted training to improve subject teaching knowledge. In the NQT+1 year this increased to 34% for subject knowledge, although only 1% specified A-level (this might indicate more limited expectations or a more unified approach to the subject). The study confirmed the importance of

providing targeted PD to early career teachers, leading to better self-reported retention in teaching (see also, e.g. Mike Coldwell, 2017).

Teacher Knowledge

The literature concerning knowledge needed for and in teaching mathematics is considerable and contested. One basic distinction is between knowledge of mathematical content (MCK) and knowledge of the pedagogy related to mathematics, dubbed pedagogical content knowledge (PCK) by Shulman (1986). PCK can be seen either as distinct or as an extension of MCK (Rowland & Ruthven, 2011). Our experience in recruiting and teaching in ITE suggests that prospective teachers more often elide these for A-level than for KS3/4 mathematics: many feel insecure in their own recalled mathematical knowledge at this level and do not see beyond resolving that anxiety. Further subcategories of mathematics teacher knowledge were proposed in an influential body of work on middle-school teacher training and assessment by Deborah Ball and colleagues (Hill et al., 2008). Teachers' subject matter knowledge was taken to include the knowledge of content that we might expect from mathematically–qualified non-teachers but also horizon knowledge that shows disciplinary connections, as described above, and specialist knowledge that includes details only needed by teachers. Teachers' PCK includes knowledge of the curriculum, of students and their mathematical thinking, and of teaching routines, examples and tasks. This framework was tested critically as part of a quantitative study investigating the effects of teachers' knowledge on practice (Baumert et al., 2009). The study showed distinct effects of teachers' MCK and their PCK on student outcomes in PISA tests, independently of classroom management, with PCK being the strongest single factor - but with no support for distinguishing subcategories within either. We see all these foci, therefore, as related aspects of teacher knowledge that might be identified as developing for or through teachers' experiences of teaching A-level.

Another framework that has been influential, mainly in primary mathematics teacher education, is the Knowledge Quartet (Rowland, Turner, Thwaites, & Huckstep, 2009), comprising 18 empirically-derived categories of classroom actions that are considered to be informed by trainees' MCK or PCK, and grouped pragmatically into four units (foundation, transformation, connection and contingency). This quartet offers a framework for relating classroom observation to teacher knowledge that has been extended to secondary teaching, focussing particularly on teachers' responses to student ideas (Rowland, Thwaites, & Jared, 2015). The focus on contingency relates to Livingston and Borko's (1990) characterisation of teaching as a complex cognitive skill which includes improvisational performance. Their study compares novice and expert teachers planning and teaching review lessons in an Advanced Mathematics (analytic geometry/calculus) context similar to that of A-level. They point out that the complex interconnectedness of advanced school mathematics requires strategic pedagogic knowledge to highlight the essential concepts and relationships and respond to significant misconceptions. Experts were found to have cognitive schema which are more elaborated, interconnected and accessible so they are able to skilfully improvise activities and questions around students' queries or comments. Novice review lessons were, additionally, less comprehensive and their explanations less conceptual. This literature suggested our research foci should include teachers' reactions to unexpected classroom events, and that observing 'review' lessons would be particularly helpful in exposing the limits of current teacher functioning.

Teacher Learning

Studies of teacher learning vary from assessments of what they know/can do at stages of their career (e.g. Schmidt, Burrough, Cogan, & Houang, 2016) to longitudinal studies of mentors and teachers detailing progression in their professional concerns and developments (as summarised in

Berliner, 2004). McCormack, Gore & Thomas (2006) followed 20 NQTs through four terms. They found that teachers' early concerns were with gaining contextual knowledge of their students, curriculum and school and with establishing classroom expectations, but that these were of much less importance by term 4. A more constant challenge was in differentiating their teaching and setting realistic goals, because their knowledge of students was limited but developing. The major and long-term areas of challenge were in the emotional and reflective work of establishing their identity as a successful teacher, and in the professional work of developing a "repertoire" that connected their knowledge of organisational routines to what they valued as the purposes of learning. This study highlights the informal nature of NQT learning compared with preservice training and suggests that expectations from mentoring may be restricted to explaining 'how we do things' and not why. Butcher (2003) also noted a lack of mentoring related to post-16 teaching and teachers' difficulties in differentiating for A-level students. For the purposes of this study, we note the areas of continuing challenge that might be highlighted in early A-level teaching and the potential of mentoring in establishing a teacher identity.

Horn (2005) also highlights the informal, social and situated nature of teacher learning (although her focus is on teachers reforming their practice rather than new teachers). She highlights two key resources for teacher learning: curriculum materials and professional conversations that classify and frame classroom experience according to provisionally articulated goals. In Horn (2010) she repackages those pedagogic interactions as 'replays, rehearsals, and re-envisioning of practice'. She argues that teachers orient their teaching to 'reform artifacts', materials and slogans which reify identity, values, and goals of the intended reform, while its particular meaning is negotiated in practice and through professional conversations. This combination of reflective conversations, recommended resources and 'key messages' to guide later teaching seems to us to characterise much of the ITE mentoring we see in schools and is likely to extend to NQT mentoring. The nature of teachers' induction will therefore be influenced by their interactions with mentors and also with other teachers of A-level.

The Study

The study takes a multiple case-study approach, in which we produce an "intensive, thick description and interpretation of the phenomenon" aiming to generate hypotheses (Merriam, 1985, p207) about the role of teaching A-level in beginner teachers' development. Each case is a teacher who had some sole responsibility for A-level teaching in their first year of qualified teaching. A-level mathematics classes are usually shared between two teachers, with the content allocated either by module or ad hoc. The five teachers were chosen to represent three different routes into teaching: two from traditional HE-led PGCEs, two from Teach First (TF) and one from a salaried school-led route 'School Direct Salaried' (SDS). Thus two of our five teachers had experienced a fully-staged entry into teaching, and were now entering their first year of full-time teaching. The other three had trained while employed as unqualified teachers and were continuing into a second year on a slightly reduced timetable. We recruited from alumni of our own institution for ease of access to NQTs with the right teaching profile and also for ethical reasons, considering that the longitudinal nature of the study, combined with the teachers' relative inexperience, could put pressure on them. Thus all participants were employed in London schools, and three in areas of economic disadvantage. Our institution has a stringent selection policy so the participants were all relatively well-qualified in their degree subjects, and had taken place in ITE deemed outstanding.

Table 1 shows the teaching and career profile of the five early career participants over three years, from their NQT year in 2014-15 to the beginning of the NQT+2 year in late 2016. We note

that only one has stayed in the same school for more than 2 years, and three have left state-funded education. This shows a slightly higher level of teacher turnover than the overall position in London.

Table 1

Participant (by route)	***Started teaching A-level in ….***	***Modules taught: in NQT and NQT+1 years (* only teacher of that module in school)***	***Shared class?***	***NQT+1***	***NQT+2***
Anna PGCE1	NQT year but some observation in QTS year (and some HE input)	D1* *Then D2**	Yes	Same school	Moved to Independent school
David PGCE2	QTS year (same school, plus some HE input)	S2 FP3 and synthesis of FP2/3 *+ C1 C2*	Yes	Same school	Same school
Chris SDS	NQT year but substantial observation/ support of A-Level classes in QTS year	C1 C2 M1 *+ C3 C4*	Yes	Same school	Moved to Independent school
Pat TF1	QTS year	C1 C2 S1 C3 C4 *+ S2*	2014 y 2015 mostly no	6th form college	Same college
Nadiya TF2	NQT year	C1 C2	Yes	Teaching abroad (no A-level)	Same school

The data collection involved five interviews with each early career teacher, one with their Head of Department or NQT mentor and three lesson observations. These took place over 20 months, interspersed by two periods of analysis and a participant validation meeting. The timing and focus of each contact is shown in Table 2. One participant (Nadiya/TF2) left the country during the study, and only completed four interviews and one observation. Data was collected over time in order to capture participants' changing reflections on A-level teaching and development in their classroom practice. After two interviews, it was clear that participating in the research was itself having an effect on the teachers' thinking about A-level teaching, in part because there are limited other structured opportunities to reflect in depth. For this reason, and because of the purposive sampling, our cases cannot be considered typical of new teachers' progress in A-level teaching. Instead they offer illustrations of how A-level teaching *can* develop in early career for teachers who are well-qualified via their chosen ITE routes, and indicate where they find support/challenge for further development.

Table 2

Time	*Nature of contact*	*Focus*
Autumn 2014	Interview with participant: 35 mins max Short interview with HoD or other responsible for allocation of AS/AL classes: pros/cons of giving early experience of such teaching	Current teaching timetable and description of AS/AL Ma/FM teaching currently being undertaken. Aspirations and immediate targets for that; initial reactions and thinking re relation to KS3/4 teaching (pros? cons?). How does this build on ITE experiences? Negotiate a lesson observation that would show what NQT enjoys and/or values and/or finds challenging about post-16 teaching.
January/February 2015	Lesson observation; follow-up interview (same day or separate, depending on participant's constraints)	Follow up reason(s) lesson was chosen. Issues, pedagogy that arose in observation that might differ from pre-16; subject knowledge drawn on; link-making opportunities with pre-16. Note in observation and follow up (20 minutes max).
	Analysis1	To inform interview schedules
June 2015	Interview (Skype option offered but free choice by participant) (30 mins max)	What has changed over 6 months wrt thinking about post-16 teaching, and also practice of that? What are emerging priorities/tensions in teaching post-16? How has it uniquely developed you as a teacher? And how does it affect how you see yourself in relation to the job? Post-16 teaching next year? (preferences, plans)
Autumn 2015	Lesson observation; follow-up interview as above	Appropriate observation to be negotiated electronically. Interview to follow up issues raised from observation.
	Analysis 2	Initial findings. Prepare for participant validation.
March 2016	Twilight Validation seminar re challenges and opportunities of teaching AS/AL	Begin to synthesise responses and issues, and seek to make progress on how general these might be. Probe re changing perceptions re post-16, impact on pre-16, impact on personal/career aspirations.
June/July2016	Final interview, with option for related observation	LO of review/synthesis lesson if possible: how did outcomes compare with intentions, decisions made within the lesson? Role of independent study? Tensions in understanding vs fluency? Sources of ideas for thinking about AL teaching? Impact on pre-AL teaching (attitude to taking risks knowledge of students)? How should a beginner teacher to be supported?
	Analysis 3	Report

Data was gathered by both authors. Joint analysis consisted of writing and reviewing individual case summaries in order to make and test cross-case comparisons. The first analytic phase generated hypotheses about teachers' initial induction, beliefs and challenges and was used to structure subsequent data collection. For example, concerns about using mathematical language precisely arose in this phase. Phase two generated cross-case descriptions and interpretations of experiences that were offered to three participants at a validation seminar, with an emphasis on identifying shared/unique experiences and asking teachers to comment on apparent tensions (for example, A-level teaching was initially said to need both more and less planning than KS3/4). This meeting also permitted a longitudinal perspective as participants discussed how their views had changed since the NQT year. The final phase of analysis used the transcript of this validation meeting as prompts to re-interrogate the data and refine the findings and their significance.

Case Studies

In the five case studies below, we offer detailed descriptions of each teacher's experience. Our selection of what to include out of our analysis for each case was guided by two principles. The first was communicating the sense of each teacher's learning over time and in context. The second was to include the details of how each teacher was inducted into A-level teaching, via the rationale given, the challenges and benefits they experienced, comparisons with other teaching and the sources of support they found.

Case Study PGCE1: 'Anna'

Anna studied mathematics at A-level and in her joint-honours degree. After considering other careers briefly, she found she was missing mathematics. Her mother is a teacher, which gave her incentives and reservations about the lifestyle, but after a year's work as a teaching assistant she felt "I really do want to teach" and completed the secondary mathematics PGCE. At the start of the study Anna was a newly qualified teacher (NQT) employed in the school where she had done her first PGCE placement. She conveyed an ongoing commitment to teaching mathematics; there have been shocks and worries but she builds on these and "really, really enjoys it".

Anna's school has single-sex education to 16 and then co-educational teaching for A-level Mathematics and Further Mathematics (FM). In her first year she taught the introductory module Decision 1 to the FM group of 11 students, followed in the summer by a few weeks of advanced pure mathematics; in the next year she taught Decision 2 to the same group (then only 4 students). Her PGCE A-Level preparation had been predominantly university-based, comprising a full week of peer-taught seminars on A-level topics. Her school placements included a few visits to A-level lessons and no exam classes. Before qualifying, Anna's new KS3/4 classes had been observed daily so she felt conscious of the contrast of starting A-level without anyone "actually watching me teach". She weighed this relative omission against remembering the pressures of the PGCE year when she had indeed wanted to concentrate on KS3 and 4.

The rationale for including A-level teaching in early career

The range of classes Anna would teach in early career was not a factor in her job decisions, but she was pleased when offered A-level teaching for her first year. In interview 1 the reactions she recalled were fairly superficial: pleasure in being deemed competent, in being able to meet the department's needs, and having a variety in class types (including teaching boys). Although she had studied decision mathematics herself, she spent "a good part of my summer working on it". At that stage she drew a distinction between KS4 and A-level mathematics subject knowledge: in the former she felt she would be "fine" attempting any student's question even if she had not seen the problem before, while for A-level she initially felt she "would not have a clue" without having worked the question herself, although once refreshed "really it was still there". In the following year, she still felt that she must prepare the mathematics more thoroughly for A-level content than for other areas, but her emphasis had shifted to predicting ahead where students would need support, that is to PCK.

Anna's Head of Department (HoD) reported he would not normally put an "untested" teacher with an A-level class, expressing concerns both about the effect on students, who are quick to react if teaching does not go well, and about the pressure on the new teacher of taking an examination class. The school usually has competition for A-level teaching but on this occasion timetabling was difficult and, on consulting senior leadership, they felt their knowledge of Anna made it a low risk decision. Without any knowledge of her A-level teaching, they justified their faith in Anna's

potential on the grounds of her subject qualifications, time and willingness to prepare and proven strength in teaching younger students. Thus, given the pre-requisite subject knowledge, A-level teaching was viewed as an extension of other mathematics teaching, perhaps more stressful and time-consuming for inexperienced teachers but not distinctive.

Both the HoD and Anna emphasised the main induction message that A-level students are just "overgrown" younger students, requiring the same engagement, monitoring and assessment. Across our cases, this HoD reasoned most strongly *against* giving A-level classes to NQTs, although in practice he felt it had worked well for Anna. He suggested that A-level showed the ultimate purpose of some KS3/4 content and hence provides a useful perspective for making decisions in planning and teaching. It also gave her within the school day a variety of intellectual challenge and of relationships with adolescents. However, for Anna's HoD, these opportunities for deeper professional thinking were valuable reasons for teaching A-level eventually, but they came *after* learning the basic teacher role – they were not *part of* learning that role. A-level teaching was viewed primarily as a privilege for future development, possibly behind a queue of other aspiring teachers. In Anna's case, although she continued beyond her first year as Decision specialist, another experienced teacher normally taught pure mathematics to all three A-level classes, and four other teachers negotiated for the applied teaching, so that she did not see how her A-level role would develop.

Reflections on learning to teach A-level

Over the five interviews we asked Anna what she had gained by teaching A-level, what she found challenging, and how it was similar to or different from other teaching. Throughout the interviews the major benefit reported by Anna has been being respected as a "real" teacher by colleagues and the students, and also by herself. She felt A-level teaching gives "the whole big picture" – academically, of where mathematics ends up and, socially, where adolescents end up. With the status of being an A-level teacher, she reported feeling that her professional experience is fully trusted by students and colleagues in the school. A-level teaching also offers Anna heightened autonomy in the classroom: there is a difference between the relative freedom she has an A-level teacher to "bounce off the students" and enjoy mathematics with them, and some of the aspects of managing younger students that "pull on the teaching, make it less enjoyable for everyone". Anna is a good classroom manager, but she welcomes the respite from having to consider divergent student behaviours, and it helps her feel successful. In this respects, A-level teaching brings Anna closer to what she presents as an idealised view of teaching where behaviour management is invisible and teaching appears to be only about students learning mathematics.

The persistent challenge for Anna from teaching A-level has been the heavy workload (or as she frames it "time invested") in reviewing her own subject knowledge, selecting resources, planning lessons and monitoring students' work. She has been tempted to cut down on A-level preparation time because "you can probably get away with it" but not succumbed. This is not only due to her professionalism, but also because detailed preparation protects her from a fear of becoming stuck or confused in front of the students. She only discussed this fear in later interviews, describing it at that distance as an inexperienced belief that instant responses were critical to teacher–student relationships. By the end of the year Anna had developed a more confident overall strategic repertoire for handling difficult mathematics in the A-level classroom, that she described as letting students get stuck, posing questions that make them think, and helping them argue it out. She purposefully selected group resources that encouraged student discussion in order to make uncertainties public, and hence showed increased confidence that her knowledge would support her in responding to contingencies. We note that Anna reports no less preparation time for this approach, but greater satisfaction as it aligns with her mathematics education beliefs.

Teaching knowledge and skills

We asked Anna to reflect on connections between her A-level teaching and other teaching. In the early interviews she considered that she was developing different skills. For A-level teaching she was much more aware of the choices made in planning and delivering her exposition, examples and questions. There was more "space" for her to assess students' responses during the lesson and adapt accordingly. For other teaching, managing the group's behaviour consumed her main attention. Later, she reflected that the A-level experience of questioning had helped to frame suitable questions for younger students. She also talked about using the A-level classroom as a rehearsal space for unfamiliar student activities and routines, adaptable later to other classes.

Although Anna spoke of wanting to see the big picture in mathematics, initially she made few explicit connections between learning mathematics at younger ages and what or how students learnt at A-level. She noticed this herself, and ascribed it to teaching decision mathematics which is completely new content for students. In contrast, her short summer experience of teaching pure mathematics made her realise the algebraic fluency needed for A-level. She felt there were more such insights to be gained when she could teach more pure mathematics. This was a contrast with her KS3 and KS4 teaching where she does now see "where all the links happen. And I need to make those in A-level". Her perception of connections in content is a strength, but there are connections with decision mathematics at the level of over-arching forms of reasoning (e.g. working with diagrams, proving, reasoning systematically) and the fact that was missing these in her NQT year shows some of her inexperience as a teacher.

Our final observation/interview with Anna saw her synthesising D2 material with students, and proactively using mark schemes with authority. She said she had learnt to do so through her own experience and "figuring out", and through asking more experienced colleagues, several of whom are assistant examiners. Much of this lesson stressed procedures, accurate knowledge, and application of mark schemes, and she was authoritative in tackling all of these, but it also offered some opportunities for deeper thinking – for example, she pushed students to diagnose errors rather than just locate them, and supported one student in meta-analysis of another's work: "he's done a 3-day split, yes, but in a really odd way" and worked through with him the implications of the mark scheme for that. More widely, she was able to build on student talk about the purposes of understanding why algorithms work, and was able to relate that to different career pathways, as well as to the advantages in relation to answering A-Level questions.

Anna's post-lesson reflection on this last visit exposed deep knowledge of her students, both as young people and as mathematicians, and she was able to both justify her approaches ("today…I wanted them just to know they've got the answers at their fingertips….it's got to be automatic") and identify ways in which she could have furthered her wider espoused aims of deepening their reflection, their metacognition and their conceptual knowledge. She identified the reduced size of the group as a significant factor in the depth of her knowledge of them, but also talked about how her KS4 students needed far more coaxing and building up of confidence, as well as how her younger all-girl groups communicated differently.

Support and mentoring

In her NQT year Anna had a weekly timetabled session with a mentor teacher. She also had an experienced department around her. Although she is the only teacher of decision mathematics, there are two teachers in the school who have taught it before. This level of potential support was a factor in the HoD's allocation of A-level teaching, and in Anna's confidence in accepting it. In practice, she has found that her mentor session is devoted to other issues and although teachers around her are "basically supportive, they just don't have a lot of time." No doubt this light-touch

support reflects the assessment that Anna's A-level teaching is sound. Nevertheless it shows that teachers in early career can be developing an important aspect of their teaching in isolation.

The kind of interactions Anna describes around her A-level teaching are those that occur because teachers share the same students rather than because she is inexperienced. These interactions are primarily organisational and concerned with standardising practice and reporting; they include comparisons of student attitudes, attainment and behaviour, scheduling of teaching and tests. To balance this, Anna has made use of online resources and enrolled for an online Teaching Further Mathematics course, in her final interview describing that as "very stimulating…it's the only time I get to really think in depth with other people."

Anna was educated entirely within the English state sector; for her next year's teaching she is moving to a local girls' independent school, citing the opportunity both to take more responsibility (she will be Head of KS3 mathematics) and to teach more A-Level. Reflecting on her development to date, Anna says:

> I'd have developed better and ….deeper I think, if I'd had more input, more observations, more regular and reasonably long mentor meetings, even this year… they never came near sixth form, it's just kind of assumed you can do A-Level teaching. So I'm hoping this new job will provide some of that challenge to what are now my assumptions, and I'll have time to do more observations, because I'll have a smaller timetable … this project has been really helpful to me because it's made me reflect on things in a way that doesn't happen otherwise, think about why I'm doing things the way I am. I miss that from the PGCE, it was very developmental and I think I needed that to be continuing still, really.

In summary: Anna came into teaching form a mathematically and professionally knowledgeable background, and with well-developed reflective skills and inclinations. Her department context was one of specialist but very busy teachers who, while happy to support her in principle, saw no pressing need in Anna's case beyond the expected weekly mentoring sessions in her NQT year. Nevertheless, she made full use of the (internal and external) opportunities afforded her, and over her first two years as a qualified teacher developed into a reflective and relatively effective teacher of mathematics up to A-Level. However, she considers she would have benefited from a continuation from her PGCE of regular informed and probing reflection with knowledgeable others.

Case Study PGCE2: 'David'

Background and Rationale for including A-level teaching in early career

David studied mathematics at university, gaining First Class Honours, and after a short career in actuarial work, decided there was greater personal satisfaction to be had in teaching and chose to train via a PGCE. He was given some A-Level teaching in his first placement school, really enjoyed it, so asked for A-Level teaching in his interview for a job there. This is an all-boys, 11-18, inner-city comprehensive, with a new sixth form in its first year when David did his PGCE placement. Unlike the main school provision, which is governed by detailed schemes of work, structures for A-Level teaching are in their infancy so every level of planning is very much the responsibility of the teacher. The school has had NQTs teaching A-Level from the beginning: the Head of KS5 explains they feel this is motivating for teachers with a strong mathematics background, and they had confidence in David as a teacher.

The school has had good support from their FMSP Area Coordinator, so has offered Further Mathematics from the beginning. Each A-Level class is shared: in his NQT year David was given the smaller teaching share for the year 13 Further Mathematics class, teaching them S2, some of FP3, and then revising FP2 and FP3 while the other teacher finished teaching FP3. In the second year of the study he had senior responsibility for the stronger of two year 12 classes, teaching them C1 and C2 while an NQT taught S1. This was a demanding induction, requiring not just his advanced mathematical knowledge but – in his first year - the pedagogic ability to build on student knowledge in mathematics that he had not previously taught (C1-4, FP2 nor much of FP3) and in his second year to monitor progress with a less experienced colleague.

Reflections on learning to teach A-level

In early contacts, David spoke at length about affect and identity. He emphasised the lack of stress in A-Level teaching relative to his main school teaching, where he felt 'swamped' by the myriad demands on him, particularly in relation to behaviour management but also in terms of the substantial school-level expectations for assessment and recording. At A-Level, the school had similar expectations for summative assessment, namely one formal test per four-lesson chapter, but he felt that, relieved of class management considerations, he was better able to think about teaching the mathematics and focusing on student understanding. He derived considerable professional satisfaction from this reflective thinking, even though he felt it was limited by the assessment regime. From the beginning, David showed an awareness of 'bigger picture' thinking, concerned that a "school obsession" with monitoring outcomes from assessments militated against the development of both independent learning and of conceptual understanding in the new sixth form. He voiced concerns about sixth formers being "infantilised", but felt powerless at this stage to act on those concerns in anything other than a low-key conversation with colleagues. He expressed frustration that while teachers acknowledged his concerns, they seemed to accept there was no alternative.

In an early interview David said "he had never felt so tired", and was not able to find time for observations, which he felt he "desperately needed in order to develop". Even by the end of the study he was still talking about "preserving sanity" being his priority in main school teaching, whereas he was able to articulate how his A-Level teaching had developed. He considered this had only been possible because of the emotional and mental professional space available in teaching A-level. He identified this as being due to the lack of high-profile behavioural issues which outweighed the greater degree of responsibility he felt for curriculum coverage and student attitudes. At every point of contact with us he expressed quite extravagant appreciation of the

opportunities for deeper reflection afforded by our visits, on one occasion referring to them as “an oasis” that “reminded him why he came into teaching”.

Towards the end of his NQT+1 year, his concerns about the distorting impact that frequent testing was having on learning came to a head when, on the advice solicited from a more senior colleague, David spent some time using test outcomes formatively to address exposed weaknesses in understanding. In consequence, his students did not cover all the material in the next scheduled unit and so performed poorly on the following test. Subsequently, David was observed forensically by the Headteacher and another senior teacher, criticised for introducing a topic from the C1 content inherent in it rather than jumping directly into new material, and placed under close monitoring. At the time of our Summer 2016 visit he talked about feeling very disillusioned, as well as under pressure to ”perform”. He said he felt low in confidence, as if, two years in, he wasn’t making progress in his chosen career.

Teaching knowledge and skills

From the first interview, David talked about A-level as a “relief” from main school teaching, in terms of being able to concentrate on the mathematics and student learning, rather than class management. He also experienced less pressure on planning, feeling “he could get away with that” with more mature learners who had opted into the subject, thus releasing time he needed for marking and main school preparation. He had anticipated “being able to treat students as young adults” but found himself surprised, and shocked, that these year 13 learners in many ways behaved in similar ways to his younger students in terms of attitude to homework or to promptness to lessons. The school adopts very similar behaviour and attainment monitoring frameworks for sixth formers as for younger students, and from our first visit David questioned the appropriateness of these for post-school progression, while also admitting the apparent, and unexpected, necessity for them. From the first interview he questioned how to balance allowing students to experience the fruits of slackness or inattention to instructions, and so learning from their behaviour, against adhering to “very constrictive” school rules, in a professional way. This remained a theme in his reflections throughout the study.

At an early stage David found A-level marking harder than for main school teaching, since he had to think through alternative solutions for himself whereas for younger students “he could just see what they’d done”. By the end of the study he was making considerable use of routines to manage his A-level workload in a way that was consistent with his value for pupil independence, for example self- and peer marking outside summative assessments, and was confident, contrary to school norms, to send a student to the library when he arrived without having attempted the homework. He had sought advice over such matters and been told “other colleagues don’t do that but what matters are the test results”.

Although David said he had spent “considerable time” preparing for teaching FP3 coordinate geometry in the summer prior to first A-Level teaching, and again the next Christmas holidays, in general in the first year he reported “living dangerously” with his planning for A-Level teaching, doing minimal preparation because he was just overwhelmed with the demands of main school teaching, and relying on his knowledge of the mathematics to ensure that “there wouldn’t be a disaster”. It was apparent in the first lesson observation (term two in his NQT year) that he had not prepared specific questions or alternative approaches that students might take, and when probed he was clearly aware of this limitation, though he saw no realistic alternative given the pressures experienced. During the observation he repeatedly re-framed unexpected student responses to align with his own preferred approach rather than accommodate different ways of thinking about a problem, though he was beginning to develop fluency in identification of student errors, and was also able to step back and evaluate his own solution, on one occasion saying “I think I’ve gone

wrong here: can anyone see where?". In terms of selecting tasks for students, he chose (in the lesson) at least one question that forced students to draw mathematics from several areas, and later, when probed as to his intentions in doing so, justified that in terms of building their deeper understanding and appreciation of the constituent ideas. He was also beginning to develop questioning described by him as "more open", and to make links across the curriculum, though for a good mathematician he appeared curiously unaware of the lack of rigour in his own talk or that of students.

Over the two years he was observed to develop a much more open and probing style in A-Level lessons, even by the beginning of the second year making much more use of student solutions and ideas, and learning to listen to those carefully and build on them. He had by then learnt to make much more use peer marking, to show more focus in the learning outcomes he wanted from the lesson, and to demand greater rigour from students both orally and in written solutions.

By Summer 2016, after an observation of a double lesson reflecting on an S2 'mock' paper, David was able to talk with confidence about the use of mark schemes, both to students and to us, questioning the validity of some schemes. He claimed this expertise derived largely from his accumulating experience of marking GCSE and A-Level papers and analysing the allocation of each mark: "you won't get the marks if…" and "there are 3 marks there – what are they for?" At this stage, we were very struck by the depth of conceptual understanding, rigour and precision he was expectingfrom these able students, including in demanding areas such as conclusions from hypothesis tests. He persisted in probing until he was confident students could not only answer set questions well, but could critique their solutions and make links across the curriculum. He made links with everyday vocabulary and fielded a variety of solutions with aplomb, sometimes making links with "what he would have done" but clearly valuing a range of approaches, and supporting students in evaluating them, as well as exhibiting both mathematical and pedagogical knowledge to make contingent links between student responses or comments and ideas across the A-Level curriculum and beyond. He also showed good knowledge of individual students, building up self-efficacy

> Did you notice that when you asked me, you then gave me your answer, that would have got you the marks? Did I particularly help? *(student shakes head*) No, not at all: you just need to be confident to access that part of your brain

but also challenging and supporting students as individual needs differed.

David's views on the comparison of A-level and KS4 teaching changed as he developed an awareness of the purposes of his teaching. He initially claimed his A-Level teaching was very much informed by his main school experiences because he used similar lesson structures (with less stressful outcomes at A-level). At the beginning of his second year, he reflected that A-Level pedagogy did not adapt to main school, where, instead of grasping the mathematics, you have to think deeply about simple concepts. At the end of the study he has started to develop a personal repertoire based on promoting conceptual understanding which applied across phases. For example, when probed about his approach to return of exam papers in an observed lesson (retaining them until students had formally reflected on their recollections of their attempts and tackled some key stumbling blocks), he said that was an approach he also used at GCSE and had found effective because students were concentrating on the state of their learning, not on the marks. Further he claimed conceptual teaching, including techniques such as making links with everyday language, as "it's what I've developed as my approach" and reflected on the connections with rigour and depth:

> at first I might have thought 'this is an A-Level thing so it's really important to understand all the bits and pieces' but … 'this is year 7 so it's OK to glaze over some things'. But now I'm less likely to shy away from really trying to say what underpins things or…using technical language…and I really try to emphasise ….it's better to spend time on something that will build their understanding.

He still points to ‘an ongoing tension’ between conceptual understanding and curriculum coverage, particularly for the frequent tests.

Support and mentoring

Even in his NQT year, David had very few conversations with colleagues, including his mentor, and observations of his teaching were restricted to main school teaching. He shared the Further Mathematics class with a more experienced colleague, but described conversations with her as “organisational, largely”. The first observation of his A-Level teaching took place after the poor test results described above, but David perceived the ensuing professional conversation as managerial and entirely focused on short-term test outcomes, rather than longer term learning. In the following research interview he reflected that the school feedback was “about as far from this conversation as it’s possible to get….. other ideas just don’t matter” and instigated a substantial discussion about the choices available to him going forward, consistent with maintaining a professional integrity. He was able to reflect in some depth on the consequences for student self-efficacy of poor test results, albeit on the basis of an inappropriate test, and the alternatives available to him that would be consistent with his values while working within school-imposed constraints, yet such discussions did not seem to be available to him within school.

David appeared self-motivated to continue to learn professionally, talking about the benefits of finding ways in which he could continue to observe others’ teaching, and also to have the kinds of reflective conversations he perceived our visits (and PGCE tutor visits) as engendering . When asked in Summer 2016 how he developed his planning and teaching, David said

> I don’t know. I read things, I think about what’s happened in lessons, I don’t get to talk much with colleagues. I really need more input to kind of sustain me in the long term. But I think, planning is a lesson is a creative act, like writing a piece of music or painting a picture, it doesn’t spring fully formed into your mind, but you create it over time and you have ideas that you play with.

Of course, our presence as catalysts of reflective professional conversations introduce an uncertainty effect into the data: it is not obvious how the thinking of some of these beginner teachers would have developed in the absence of such conversations, which Baker and Johnson (1998), and Peng (2007) suggest are themselves conducive to professional learning.

Two years after qualification, David professes himself “more interested in developing his teaching” than “climbing the career ladder” but remains committed to an ideal of comprehensive education and of developing as an effective teacher of the range of young people. He clearly sees his future as featuring significant quantities of A-Level teaching, and, despite the episode of what David experienced as painfully critical monitoring, the school seem happy to timetable this.

Conclusion

David came into teaching with a strong mathematical background, and two years after qualification, appears to have developed into an unusually reflective, supportive and enabling teacher, with good subject knowledge for teaching and well developed subject pedagogical knowledge. Over the two years of the study he showed clear development in a number of areas identified by Berliner (2004) as distinguishing expert functioning from that of a novice. However, he still describes much of his main school teaching as “survival” and is frequently struggling to synthesise his own professional values with the enactment of school policies. He finds A-Level and main school teaching development symbiotic but has quite limited confidence in his own effectiveness, which has been undermined by recent performativity questions (Ball, 1993). His initial A-Level teaching experience was highly demanding. David has had little planned or informal support for developing the depth of his practice, yes he remains committed to his mathematical and educational values.

Case Study School Direct Salaried: 'Chris'

Background and rationale for including A-level teaching in early career

Chris undertook a school-led route into teaching after an Oxbridge degree in Engineering and several years working as a mechanical engineer. He had seen his brother teach, and in his QTS year said he perceived it to be a more "meaningful" career than his jet-setting, highly paid but pressured engineering job. His mentor (the same for QTS and NQT) encouraged him during QTS to observe and support A-Level classes, of which the school has plenty – seven in each year of this large boys' comprehensive. By February of his training year Chris had been offered a job at the school and had already identified that he would like A-Level teaching to be part of that.

In his first term as an NQT, Chris was allocated M1, and a little C1/C2 teaching for each of two year 12 classes. His Head of Department said they were needed A-Level teachers and were confident to include Chris because they already knew that he had both sound subject knowledge and good relationships with students. She added that additionally, the timetabling gave opportunities for her to plan jointly with Chris, while he was keen to learn and quick to ask for support and ideas. She saw the advantages to Chris that there was more scope and subject interest at A-Level, and that he would see more of boys' progression in learning. Advantages to students were that he would be able to teach in the main school to pre-empt misconceptions and insecurities that manifested themselves in A-Level classes.

Reflections on learning to teach A-level

Chris was initially clear about his motivation in teaching as "being of value to society", though he made few ongoing references to the values that he says brought him into teaching from engineering. Despite the positive, outgoing persona he cultivated, he repeatedly returned to feelings of being drained by unrelenting expectations, and over time expressed increasing frustration with the challenges of teaching less mathematically-inclined boys.

Chris described in his first interview how his previous year's observations already informed his main school teaching, citing year 12's weak algebraic manipulation in particular. During the summer between QTS and NQT years, Chris was encouraged by his mentor to do an FMSP 'Introduction to A-Level teaching course, and then to enrol on non-masters TAM, and he claimed these courses gave him greater confidence, knowledge of the whole A-Level curriculum, and also familiarity with many of the Integral resources, which he was at that point "using intensively". He claimed these resources were very helpful both in terms of developing his subject knowledge and his teaching of the material. The school tends to make very little use of textbooks, though students are recommended one to buy: instead, they use a VLE to set work and students are expected to make notes during lessons. Chris himself said he occasionally used the textbook for reference.

At that point, Chris said he felt valued by being given A-Level teaching. He enjoyed the more mature relationships with students, and the A-Level-focussed discussion he had in regular mentor sessions, given his mentor also teaches mechanics. However, he also said that, given the enormous time pressure in this NQT year, he was not yet preparing in enough detail for A-Level classes. He appreciated the need for more thorough planning after some "awkward moments", but considered it had less cost than insufficient planning in main school teaching. He attributed this awkwardness to not yet having built up a sufficient knowledge of students' mathematical thinking at A-Level to understand what had gone wrong in his communication with students and so being able to respond contingently. He felt older students needed "different repertoires" for dealing with missing homework, lateness to class, etc., and that added to pressure on him. In fact, challenges to student working habits came to a head with one of his classes (28 students) shortly after our first visit, and

Chris was supported by his mentor and Head of department in developing his own responses to that. Chris described these as "Draconian, infantile really – part of me feels they shouldn't need that at this stage, but they clearly do."

Teaching knowledge and skills

When we observed him in his NQT year, Chris was beginning to use differential questioning in his teaching and frame his responses in motivational, aspirational terms; he was also able to explain his selection of tasks in terms of their different demands and his knowledge of the students. However, many of his explanations, and the responses he accepted from students, lacked mathematical rigour, and despite his academic background, he seemed unaware of this. One feature of his working that Chris claimed was distinctive to his post-16 teaching at this stage was the use of student voice: he talked about "feeling freer to learn from students" than in the main school, where class control, though not an enormous issue for him, was still an ever-present factor in the choices he made. He claimed the TAM course was allowing him to persist with more challenging approaches than "feeding it to them", in part through meeting with others in the same situation but mainly through providing rich materials that he knows will work but could not prepare himself. In fact, for the whole study the lessons observed were closely based on Integral resources, and Chris said that was typical – "they're so comprehensive, I don't see any need to go beyond them." At this stage, he was also beginning to abstract from these resources some, approaches and tools he then used in main school teaching: he described his A-Level teaching as "a continuum" from KS4 of what he hoped was developing good practice, and that was a way of thinking his mentor encouraged. However, over our period of contact with him such transference and thinking remained at a comparatively particular, rather than general pedagogic, level.

As is typical at the school, Chris shared each class with one other teacher, in both cases highly experienced, and he talked about shared talk being very supportive in helping him make links between his developing pedagogy and individual students. As an NQT, it was clear that Chris had made significant development to his skills in resource evaluation, pedagogic approaches, and link-making since he was observed (by one of us) in his QTS year, but his contingent response to unexpected student questions or situations at A-Level was still in its early stages.

By the end of that NQT year, Chris had realised that, despite his welcoming of student voice as appropriate to older adolescents' environment, he was still struggling to balance his own classroom efforts with those of students. He pointed to a year 12 observation as critical in helping him identify that as an issue, making the link with a similar comment made to him about main school teaching the previous year. He reflected on his apparent slowness to recognise (again) the limitations of exposition as needing to get beyond his own relationship with the mathematics in order to engage with students' mathematics: "I wasn't as familiar with the material, at least I was, but not in a way for teaching." He reiterated that he now conceived his teaching approach as using "much the same techniques right through the school, just adjusted for the age group so if anything I leave the sixth formers to sweat a bit longer", and quoted the use of Integral-inspired active revision techniques" as an example of transference between from A-level back to KS4. He was also able to reflect on the ways in which he had learnt to drop things into main school teaching as a result of his A-Level experience, particularly in relation to algebraic fluency, which he identified as a key focus if students were to survive in A-Level mathematics. At this stage, he talked about A-Level teaching needing more preparation than main school, largely because, even with support from Integral for the 'big picture' and specific approaches, he now did most of the examples used himself to see their potential and pitfalls.

In his NQT+1 year Chris retained the more diverse of these classes, though now much reduced, for C3/C4; he also took on a year 12 Further Mathematics class for C1/C2. In the Autumn

observation, he both demanded, and used, more rigorous mathematical communication. His planning showed some careful structuring he was able to justify, although also some lack of thought about the progression of questions used.

In the final observation, Chris ran a revision relay with a year 12 class, for much of the (double) lesson, with the class's other, more experienced, teacher in attendance. The contrast in response to student solutions was very marked, with Chris's responses very much more closed and limited, and about procedure and gaining marks rather than focused on conceptual understanding while his partner teacher managed to incorporate both. This matches Livingston and Borko (1990) identification of 'review lessons' as a site where early career teacher functioning is exposed, though conclusions from a single observation must be limited! On probing after the lesson Chris continued to talk about how important conceptual understanding was to him, but seemed unaware of the opportunities missed.

Over the course of the NQT+1 year, Chrise was observed to be more methodical about making links across the curriculum, and supporting students in articulating synthesis of that, as well as more effective in responding to unexpected questions or comments. He talked about the importance for A-Level students of developing independent working habits, though he was not able to point to any actions he took in his main school teaching to support preparation for that. Chris commented on the connections he now appreciated between preparing mathematics for A-level teaching, gaining experience of students' thinking across the curriculum, and the success of his lessons: "the more you know the more you can do with them, the more you can stretch things and really push them on and take it to the right places." However, those aspirations were not fully reflected in observations, where, even with further ideas and prompts available from Integral, he was not yet able to fully harness the potential of some questions for learning. Throughout, Chris talked about "the importance of conceptual understanding", and that was the main theme of his reflections about the relationships between main school and A-Level teaching; however, while he transferred some of the *structures* featured in Integral activities to younger classes, and happily used *specific probing questions* that featured on Integral, he appeared not to be able to articulate the transfer of *intent or depth* of those either to new contexts within A-Level teaching, or to his main school teaching. Indeed, when at the end of the study he talked about learning from his (comparatively weak) year 9's the value of setting a page of examples in order to help students "settle down and get on", since "even sixth formers just need to get on and practise", he appeared still to be largely undiscriminating about the nature of that practice.

In early contacts with Chris as an NQT, he talked about "developing confidence", although in the classroom the persona projected was already that of a lively and positive teacher. During that year the distance he maintained between himself and year 12 students varied, and Chris referred to that as "still trying to work out how mature they really are". Students sometimes appeared unsure how to respond to some of his more relaxed comments. Observations during the next year showed more consistent relationships with students and, although he had welcomed the reduced managerial tensions of A-level classrooms he reflected that feeling "a little bit unsure of yourself" had been a downside of his A-level induction, which did not fit his public teacher identity. Over the course of the study, he claimed a growing confidence, for example to cope with very bright boys in his classes, whom he might have found a threat the previous year. He maintained an active learning disposition, talking in NQT+1 about how he enjoyed re-learning the *(A-Level)* mathematics from a more mature, teacher's, perspective, and that he still had quite a lot to learn, especially about Further Mathematics content, so he got the whole picture. Throughout his three years at the school he maintained active harnessing of colleagues' knowledge and skills, in a department where those were freely shared and where professional talk frequently went beyond the procedural seen in many schools.

Support and mentoring

Chris's QTS year mentor was proactive in encouraging him to investigate A-Level teaching, and to attend the TAM course. As their relationship developed during the QTS year, they had sometimes focussed specifically, in both discussion and some observation, on A-Level teaching. During the NQT year, regular mentor meetings largely focused on practicalities of getting to know the context of students and school. In addition, Chris reported that he tried to reflect on what's happening when he could find the time but was now beginning to appreciate that the type of thinking that permitted reflection been "bullied" into trainees during the ten training days received during QTS (at our institution) and that such opportunities were harder to create for oneself. He was encouraged to present work from TAM to the whole department, which he said helped him reflect on the content in more depth.

During his NQT+1 year, Chris did not have formal mentor meetings but continued to harness wider department expertise. He talked about ideas culled from department meetings, about occasions when he'd approached colleagues informally and asked for specific teaching ideas, and for guidance on likely misconceptions and issues that were likely to arise. In particular, he articulated the benefits of being 'paired' with a strong experienced colleague. Interestingly, when probed on the importance he gave to conceptual understanding, he expressed dissatisfaction with the pressures for year 11 students to perform in examinations, and the limitations this placed on the development of independence and of deep conceptual understanding. However he had not talked about these issues with colleagues, and did not seem to perceive himself as having any choice but to 'teach to the test', though that was not a view held by his mentor, for example.

Chris himself had been brought up within the state system; nevertheless, by summer 2016 he had acquired a job for September 2016 in a local prestigious independent school. He claimed "very mixed feelings, in principle: I do care about all young people learning mathematics", but said he felt driven to find something "less draining, less all-consuming" than working in his present school – and also that he found teaching the older, more academic boys much more fulfilling than "teaching the ones who find it really difficult to learn".

Conclusion

Chris received regular and conscientious mentoring, including for A-Level teaching, throughout his QTS and NQT years, in a supportive, mathematically-communicative and A-Level-active department. In his A-Level teaching he benefited from sharing classes with a variety of experienced and clearly effective teachers. However, his reflection was not, and did not become, as deep as one might expect given his academic background and this support: we wonder if his school-led route, with more restricted time and space for deep and informed reflection, might have limited that. Chris developed significantly as a result of the TAM course, taking that as a model approach for A-Level teaching, but in two years' teaching of A-Level he did not fully harness its depth, and although he transferred some of the structures to his main school teaching, we saw no evidence the TAM pedagogical philosophy had permeated his thinking about main school teaching. It would be interesting to know how that develops in a new environment. Chris had no doubt he enjoyed A-Level teaching, and by the end of two years he appeared confident and also reasonably effective, though he had not yet developed a repertoire consistent with his claimed priorities. In many ways he appeared to have 'learnt the talk' of deep conceptual understanding without engaging with its meaning or implications in depth.

Case Study Teach First 1: 'Pat'

Background

Pat was a mathematics enthusiast at school, studying Further Mathematics A-level independently using FMSP resources. She then completed a mathematics and statistics degree at an elite university, where she volunteered as an A-level tutor. After a few years in civil engineering, she joined the Teach First route to train as a secondary mathematics teacher. A-level teaching was central to her decision to enter teaching:

> Even when I was doing A-level maths I remember thinking, I'd quite like to teach this. And (when) I went to university…I volunteered as a tutor of A-level maths and I really enjoyed doing that. And it was A-level maths that made me want to be a teacher. So it's really important to me to teach A-level maths.

Pat had been given a shared Y12 class during her QTS year, which she welcomed as she felt "confident to teach anything". At the start of the study, she was entering her NQT year in the same school and had new year 12 and year 13 classes. Pat presented herself as committed and enthusiastic but at that point she was occupied by the goal of managing the challenging behaviour of main school classes. She described A-level teaching as essential for her relief and motivation:

> I actually feel like I need it to make the week... It makes it sound like I hate my other classes; but...it's a different kind of hard work with the sixth form, which I don't always experience with...the other classes. And just feeling like if I teach something well you see the result, which I enjoy. I find the mathematics genuinely interesting as well.

Pat's Teach First placement was in a mixed, 11-18 school offering Mathematics and Further Mathematics, where most teachers with mathematics degrees teach some A-level. In her QTS year she had shared a year 12 class with an experienced teacher, teaching Core 1, 2 and Statistics 1. She felt she had made several mistakes with this first class, described below, but she also felt equipped to build on this experience for her new A-level classes. Half-way through the study, after completing her NQT year, Pat moved to a sixth-form college, to teach the range of A-level core and statistics modules and one GCSE resit class.

The rationale for including A-level teaching in early career

Pat was invited to teach A-level by her Head of Department (HoD) who was also her QTS mentor. She took pleasure in the invitation, citing a match with her subject knowledge and also her personal motivation: "I really enjoyed A-level mathematics, even when I was doing A-level mathematics I remember thinking, I'd quite like to teach this. It was A-level mathematics that made me want to be a teacher". Although she had hoped for A-level eventually she had not actively considered how it would be introduced, and she was surprised at status it gave her with some students and people outside work.

Pat and her HoD had discussed the rationale for teaching A-level and, in their interviews, they offered the same two main reasons. The first reason was that A-level teaching draws from the same mathematical knowledge base that enhances GCSE teaching, so is an expected professional role. The only exceptions are for teachers bringing limited mathematical knowledge to the career, or those who seriously lacked in confidence. The HoD expressed doubts about ever giving A-level to teachers who did not start with mathematical confidence. She did not anticipate finding the external support (e.g. through FMSP) or enough of her own time to monitor the ensuing risks for an exam class.

The second reason was that A-level teaching "gives you the chance to teach the subject without major behavioural issues, which actually is a really positive thing for new teachers to experience" (HoD). In her first year, Pat articulated this reason mainly as a relief from the stress of

training, welcoming a chance to reconnect with mathematics and the vision of herself as a successful teacher. As in the first quotation, Pat contrasts her pleasure in returning to mathematics with the new struggles she is facing through teaching, and also opposes the satisfaction of making progress by re-learning mathematics to the statis of repeatedly meeting student obstacles. Her HoD echoed this view, arguing that A-level teaching is "relaxing" because there is less need to "facilitate" and manage students into learning. She added a professional development perspective, framing A-level as a valuable microcosm of experience: an opportunity to learn in close-up over a 1-year course about the interplays of teaching, learning and assessment.

Pat's HoD was the only one in our study to endorse NQTs teaching A-level because it developed core teaching skills (rather than developing complementary ones). She also argued for including compulsory A-level experience during PGCE placements (minimally observing lessons and, ideally, team teaching) so that trainees would gain this microcosm experience and be "realistic" about what A-level teaching demands. In later interviews, Pat herself reflected on how the more forgiving atmosphere of A-level had allowed her to improve her teaching routines, including: rehearsing practical resources or group organisation for complex activities, adapting tasks and transitions on the spot to have a better effect on learning, standing back and listening to assess students could rise to challenges, building in repetition and explicit connections. At the end of the study, she characterised A-level as the field in which she could be a "creative" teacher, returning to her characterisation of successful teaching as involving change and developing the ability to affect dynamic outcomes.

Reflections on learning to teach A-level

At the start of the study, Pat actively drew on her previous year's experience, reflecting that her most significant mistake had been to assume the students were already independent learners. She recognised that allowing students to fall behind with homework, ignore revision and avoid exposing their understanding had led to poor test results: "I'd maybe be a bit nice about that and then realise a bit later I should have been way stricter about those things". Eventually, discussion of the issues and reinforcement (with her HoD) enabled her to impose new behavioural routines on the class. Pat returned often to the message given by her HoD that year 12 "have just left year 11" and continued to advocate "phoning their parents, emailing them and nagging them loads." By the end of the study she was starting to consider subtleties, for example debating whether referring students to attend after-school catch-up classes promoted their independence.

Pat and her HoD agreed she had also misjudged students' ability to take on new ideas. Her overall approach to A-level and the way she planned lessons started from her own mathematical background, re-working the mathematics for herself, including any proofs, and enjoying the challenge of seeing how to break it down. Aligned with this, she had initially seen the years 12s as "university students, intellectuals" and was keen for them to gain the conceptual understanding that made mathematics easy for her. However, reflecting on her lessons showed Pat that she should not always teach things in the way that she understood them: "I kind of realised after a while that sometimes my explanations weren't working. I'd be quite keen to prove something before they really...they weren't ready for that". By the end of the study she still aimed for conceptual understanding but had added two priorities to her planning: finding out what students found difficult and creating early opportunities in each lesson for students to explore and discuss new ideas.

One major challenge in teaching A-level was the workload needed for planning. Pat felt under great pressure from her HoD to plan carefully for particular KS3/4 classes where behaviour could deteriorate. At times, she had rushed A-level planning, relying on her mathematical knowledge, but always "felt awful" about the outcomes. So, even though she did not fear the same "drastic"

consequences as with difficult classes, she pushed herself to plan lessons thoroughly. In later interviews she commented that this was not given a high profile by the department. Pat had decided to leave teaching altogether during her second year, and her move to a sixth form college instead was inspired by seeking colleagues who would prioritise excellent A-level teaching.

The benefits that Pat experienced from A-level teaching were significant. It affected her retention, since her comments suggest she would have left teaching without it. It became important for her self-esteem as an area where she could see herself improving and she actively enjoyed the work needed for planning and evaluating. It helped her improve as a teacher by focusing on the relationship between teaching and learning at the level of individual students' needs rather than maintaining a consistent whole-class awareness to identify emergent behaviour problems. Thus the HoD's rationale for giving A-level to early career teachers was well-founded for that school in the short term, and for Pat's teaching career in the medium-term.

There were other benefits that Pat articulated. In every interview, and in observed lessons, she talked about her love or joy of mathematics. Initially this sustained her enjoyment of the job, and later it became an important way of building relationships with students. She consciously enacted a "lame" enthusiasm ("acting as if everyone is just loving it") to permit a classroom atmosphere of mathematical engagement and open discussion, a strategy which then helped her assess student learning. She was purposeful in giving specific praise to those who struggled, as a way of including them in this atmosphere.

Pat's mentor suggested that the deeper understanding she gained through A-level mathematical teaching and learning helped to improve her teaching generally. At her mentor's suggestion, she trialled practical activities and group organisation with the smaller classes of more mature students before using them in other classes. When she took on higher KS4 sets in her second year, she was familiar with the algebraic and graphical skills they needed and knew what to emphasise beyond immediate GCSE requirements. However, for most of the study, Pat herself continued to make distinctions between the key stages. Some of these relate to the amenability of the students, for example she did not feel able to adapt main school lessons in order to improve learning: "If you're being a bit more flexible it means your transitions are a bit more shaky in a way. Which is fine, if the class are on your side and behaving". Some also relate to the mathematics covered: she found the A-level curriculum more compact and connected than GCSE, so that it was easier to remember where students are and guide them to "access it at different levels". If anything, Pat reported the opposite: that the teaching routines she had learnt for KS3/4 were useful when applied to A-level. Apart from the close monitoring of homework, she used starters to settle classes and she built algebraic fluency through repeating exercises with small variations. In her last interview, she conjectured that, if she returned to 11-18 teaching, she would now have a different attitude to talk-based activities in key stage 3 ("talking time is not to be off task") after having seen the benefits and learnt to manage them with A-level students.

Support and mentoring

Pat was supported by a conscientious and skilled mentor/HoD for QTS and NQT. Nevertheless she was eventually disappointed that her approach to A-level teaching was "not really questioned", a lack that felt critical when she was coming to see A-level as central to her teacher identity. Her mentor was certainly aware of early issues and backed her interventions with lazy students, from which Pat developed the key message we summarise as 'year 12s are overgrown year 11s'. However she spoke of these as Pat's early mistakes, which had been resolved. Behaviour management was a more important challenge for some classes, so that Pat's A-level development during the second year was only critiqued indirectly by monitoring her students' achievements.

A-level classes in the department were always shared, usually pairing more- and less-experienced colleagues. Pat experienced this working in different ways: one colleague divided up the syllabus and then taught her content independently, whereas she was pleased that others were in principle willing to liaise and be consulted through the year. Looking back, she recalled that there was only one teacher in one term with whom she had discussed pedagogic issues of A-level teaching, as opposed to resolving management or student issues, and that she had no A-level observations until she requested one at the end of her two years in school. In her college teaching, Pat was already a competent practitioner, but she particularly valued that the department discussed and set teaching goals such as promoting discussion, and had an established practice of sharing and feeding back on each other's lesson plans.

Conclusion

We see Pat as a case of a professionally aware but often stressed and exhausted young teacher finding her teacher identity in A-level. Initially, A-level teaching helped connect Pat to her reasons for choosing to teach and the enjoyment she had felt during school and university in communicating and inquiring within mathematics. Pat's HoD was unusual in framing A-level teaching primarily as an essential part of learning to teach, rather than a later privilege, a contrasting relief or as developing complementary skills. In practice, Pat's teaching skills developed differently in main school and in A-level teaching so that in main school teaching she was highly attentive to transitions, closed instructions and routines that reinforced predictable behavioural outcomes. In A-level she used some of these routines but also valued discussion, open tasks (such as the Integral resources) and group work. Her inability to resolve these different teaching repertoires in the school context put her future in teaching at risk, and this was resolved by moving to a post-16 institution. Although Pat is wary of accepting any restrictions to her future teaching career, she appears strongly committed and suited to working in an A-level and post-16 environment, appreciating its satisfactions, intellectual challenge, pedagogical intensity and collegiate working practices.

Case Study Teach First 2: 'Nadiya'

Background

Nadiya came to teaching through the Teach First (TF) route at IOE and was starting her NQT year at the beginning of the study. She had not taught A-level in her QTS year, and her previous experience of exam classes was with a small year 11 set with whom she had tackled only some of the higher level GCSE content. Nadiya had A-levels in Mathematics, Biology, Chemistry and History, and had originally aimed for a science career, but during her sixth form decided on a History degree. In applying for Teach First she knew that she might be asked to teach outside her degree specialism, and her initial offers were for both science and mathematics. She felt mathematics was the subject she was "best at" in school, whereas she lacked the practical knowledge for the TF science knowledge audit, so she was pleased to get the mathematics placement.

Nadiya was teaching in a small, 11-18, London girls' school with a high proportion of students eligible for free school meals. In her NQT year, Nadiya was given one double lesson a week with a year 12 class of eight students. There was a planned support structure for her teacher development, involving paired teaching and regular mentoring. During the year, she was also sent on the six-day non-masters Teaching Advanced Mathematics course. The school had been strongly affiliated with Teach First for several years and was noted for its strong response to the needs of new teachers who might otherwise feel "chucked in at the deep end" (HoD). Although Nadiya intended to teach A-level eventually, envisaging studying the Further Mathematics content to extend her own knowledge, this aspiration "went out of the window" when faced with the early workload of teaching. Therefore she did not actively seek A-level teaching in her NQT year and was pleased that her HoD found her capable. By the end of the year she had not significantly changed her view and described herself "mainly as a GCSE and key stage 3 teacher who just teaches sixth form as well once a week." After completing her TF placement, Nadiya took a new post as mathematics curriculum leader at a small, 5-16, international school in Southeast Asia, where she could enjoy opportunities to travel and take on new responsibilities.

The rationale for including A-level teaching in early career

Nadiya took on A-level as the next stage of her induction into becoming a mathematics specialist and a full team member . By the end of the year she confirmed that the main advantage was the improvement in her subject knowledge, allowing her to teach and appreciate progression across the whole mathematics curriculum. She also noted that this increased her job prospects, and had allowed her to indicate competence in teaching high-attaining students when she applied to an independent school.

These reasons echoed the HoD's rationale for introducing A-level in early career. Being a "crucial" exam class, A-level was not on offer during the QTS year: the HoD wanted to know more about the member of staff before giving them that sort of "responsibility and privilege". For an established NQT, however, he saw A-level both as a departmental staffing strategy and as part of explicit career development strategy by which teachers should take on group responsibilities:

> It's just my own philosophy that I think that we're a team and we should. As a head of department I want to be involved in each key stage, and I would expect the same of the rest of the department as well. I think it's good for subject knowledge as well. I think it feeds into GCSE teaching; if you're teaching the A-level work then you're more comfortable with the higher level GCSE work.

For the department, the HoD he felt the structure of teaming up experienced and less experienced staff ensured sustainability and flexibility in a school with high staff turnover, and did not let the teaching "stagnate". He was keen that there were no "divisions" or specialist teachers in

his team. He had taught A-level himself as an NQT and valued the vibrancy, hard work and fresh information offered to students and the school by early career teachers.

Developmentally, he explained that he had seen several TF trainees who had not studied mathematics since their own A-level become successful post-16 teachers, which meant that he did not see prior knowledge as limiting. Although subject knowledge was not an entry criterion for him, it was clearly his priority in teacher development: he worked on mathematics problems in department meetings, and valued the IOE-based training sessions that focused on "doing actual mathematics, sitting down actually doing hard examples of what A-level mathematics is". As in the quote above, he argued that each key stage was enhanced by horizon knowledge of the next, but offered no detail about exactly how to deploy this mathematical knowledge to improve pedagogy. Beyond the subject knowledge (MCK) benefits, he suggested that small classes might provide a welcome chance for teachers to excel if behaviour were an issue elsewhere. He referred also to the whole-school "key stage 5 ethos" in which students are encouraged to be leaders: he argued that A-level allowed new teachers to appreciate how adolescents develop and what vision of young adults the school is aiming for. Overall, he placed A-level teaching as a later stage on a continuum of teacher development, a complementary rather than contrasting practice.

Reflections on learning to teach A-level

In looking back, Nadiya considered that her AL teaching informed her approach to main school teaching and assessment mainly through understanding connections and progression within the school mathematics curriculum. The examples she offered used her knowledge of how mathematics could be applied and extended to plan teaching that combined basic fluency and mathematical reasoning. As an NQT, she used bin-packing algorithms (from the A-level module D1) as a context for year 7s to practise addition and subtraction in an optimisation problem. Later, in her curriculum leader role, she used logarithms as extension work for year 11s who understood indices, and drew on her experience of AL to frame the school's performance descriptors of secure and exceptional knowledge.

During the interviews Nadiya spoke at length about meeting the challenges of teaching A-level. However her response to these showed that she was also gaining pedagogical insights by trying a range of strategies and evaluating their effectiveness in becoming "the kind of teacher I want to be". We are not able to say that these insights did not, or would not, develop in teaching other classes, but they were articulated in an A-level context.

Nadiya's main concern was the workload needed for mathematical preparation prior to planning, finding it much more demanding than for other classes. She spent one evening a week working the relevant mathematics questions before planning each lesson. For C1 she found this matched her own A-level experience of "flying through it and really enjoying the revision" but for S1 and C2 she found it demanding to complete some of the harder questions that students would attempt. Although she saw herself as a student who "liked to learn one formula and then I could manipulate it however I needed it", in contrast to students who wanted a list of everything, she also realised that in some areas of A-level she too had "learned the rules rather than understood where the rules came from." She reflected that she now understood mathematics much more because she had the goal of being able to explain it.

One driver for this workload was Nadiya's anxiety about maintaining her authority as a confident teacher when she was not a mathematics graduate. Initially she was nervous that students would "have a more intuitive understanding" than she did, and would be bored by her lessons. In just a few weeks of teaching, while her HoD was still present, she realised that she needed to "break it up" just as much as in other lessons. Her thorough preparation was apparent in the observed lesson, which built up meaning from students' prior knowledge, included clear

transitions and showed applications to problem solving. However, reflecting on this planning, Nadiya felt she struggled with "the best way to think about" mathematical content, particularly when there were many different representations and connected approaches offered in textbooks and online resources.

Some of the challenges – and the pedagogic learning - that Nadiya experienced while teaching indicated her relative inexperience of using A-level concepts within more sophisticated mathematics. This was partly evidenced in her attention to using language precisely in her explanations. In an early interview, Nadiya considered the kind of language errors she made in a GCSE class as just "saying the wrong thing" (for example saying pi instead of theta), arising from unfamiliarity. She compared this with the realisation from A-level that her use of language sometimes blurred conceptual distinctions: for example, until teaching radians, she had not distinguished the concept of angle from its measure in degrees. We also saw effects of her relative inexperience in making decisions about what to emphasise when problems allowed multiple approaches. During a lesson on radians, she modelled solving a geometry problem in degrees but was then told by a student that the textbook answer was given in radians. Nadiya repeated this to the class, without comment, and moved on. Her reflections afterwards detailed her dissatisfaction with this moment. On the spot, she had been balancing the affective impacts on students of reworking the whole problem in radians (leading to boredom and/or certainty) against the desire to model exactly what would be expected in an exam (finding a cue to use radians). She explained that her pedagogic decision-making about what to say/do was hampered by her discomfort in not knowing whether it really mattered: whether her answer was correct, and whether it would be valid simply to convert it to radians. One would expect a mathematics graduate to have fewer considerations vying for attention since he/she would be likely to appreciate that it is only in calculus that it matters whether you work in radians or degrees. We noted that Nadiya did not speak of big connecting ideas (such as proof or functions) during her interviews, but was interested in sorting out the ways of understanding within topics rather than between them.

During her NQT year, Nadiya became increasingly interested in her own vision of herself as a teacher as opposed to her capacity to fill a generic teacher role. She spoke repeatedly about wanting herself and the students to become more "engaged" during lessons. She had developed several classroom routines, initially aimed at minimising the risk of making an error. Some of these were teacher-centred, such as working all questions or writing the necessary formulae on her slides. However she also explained two strategies that increased student engagement and share some of the responsibility for doing mathematics: asking students to suggest next steps during explanations, and to consult each other during exercises. She found it easier and more helpful sometimes to listen and comment on student thinking than to generate all the mathematics. More importantly, she was starting to change the atmosphere in the A-level class away from working in silence. Drawing on her experiences with KS4, Nadiya found it "unnatural" to allow her small class to work independently: I feel like I need to be doing something, checking they're all right, checking they're doing something. But I know that sometimes they just don't need that and they need me to step back and they need to think about it for themselves". During the NQT year she started to move away from textbook work and used card sorts and tarsias made available through TAM. She saw the advantages of these as requiring students to talk to each other. She felt "enjoyment" as a teacher in engaging with their conversations, and we observed her using these to assess progress and identify misconceptions or fruitful mathematical problem solving reasoning that she then shared with the class.

By the end of the year, Nadiya had developed her thinking about A-level teaching, even if she did not always articulate this explicitly, and was starting to prioritise mathematical activities that allowed her to respond to student thinking. In moving to a new and very different school, this

aspect of her development was (temporarily, perhaps) halted since the workload in her new role meant she simply adopted available schemes of work without time to adapt them. Her thinking about mathematical language was also interrupted since she saw her new challenge as incorporating more visual and graphical communication in a context where students' English language skills were less developed.

Support and mentoring

Nadiya benefitted from a more planned support structure than our other cases, in a school with an explicit career development programme. She shared her class with the Head of Department (HoD) who was timetabled as a second teacher for her lesson, and they interacted to teach in a single progression rather than dividing topics between them. After a few weeks she was left to teach the class independently but continued regular contact with him about "structural" concerns such as lesson content. She also had weekly meetings with her mentor, who taught the parallel year 12 A-level group, sharing them in a similar arrangement with another NQT in the department. These meetings were" 95% A-level" and they discussed "the actual pedagogy of the broader concepts." There were also informal discussions, for example about solving particular problems or exam coaching.

Nadiya valued all these forms of support, but noticed that they modelled a particular approach to A-level teaching that she characterised as "more of a chalk and talk. This is the example, and now you have a go" whereas she was interested in developing a more engaging pedagogy. Although she had had very strong guidance in improving her mathematical knowledge, she ended the year feeling that there had been scope for her to develop more as a teacher, but that she had needed more exposure to varied teaching models.

Conclusion

We interpret Nadiya's case as showing a strongly-framed system of accelerated career development, and a teacher for whom A-level teaching was primarily a way of deepening her curricular knowledge of school mathematics. Nadiya is a successful product of the tenets of the Teach First route: she works hard for her students, takes on responsibilities and has quickly progressed to a leadership position while simultaneously developing her personal plans to travel widely. Although she has moved abroad, Nadiya speaks of herself as continuing to progress in the profession, able to offer unusual experiences that combine her English experiences with the South-East Asian context that is seen as prestigious for mathematics education. Our observations were necessarily limited, but indicated that Nadiya would have benefitted from more pedagogic guidance in teaching A-level and becoming supported to better understandstudents' thinking. We also note that the connections and emphases that she had started to develop within mathematics, such as using precise language, were restricted by her experience being limited to school mathematics so that she did not engage with 'big ideas' such as proof.

Findings and Discussion

How early career teachers are inducted into A-level

We selected five teachers who had successfully qualified and already been offered A-level teaching in their NQT year. Interviews suggest a common induction experience is to take responsibility for the lesser share of a year 12 class, covering the pure mathematics content (in C1 and C2), and with a more experienced teacher taking the other lessons. In practice, two of our five teachers started with different content, Anna with decision mathematics only and David with Further Mathematics. Both were known and trusted after PGCE placements in these departments, which had staffing gaps in these specific roles, but there was no evidence of any adaptation to their mentor support to take account of this non-standard beginning.

Rationale

In the early interviews, the rationales offered by EC teachers for embarking on A-level teaching echoed closely those of their HODs or mentors. There is a strong message that A-level teaching is not automatically given to NQTs so that allocation arises from a serendipitous match between the perceived strength of the teacher and current staffing needs. A-level would normally only be given to particularly well-known and well-prepared NQTs (in terms of both subject knowledge and pedagogical skills), and indeed all our sample were known by the school from their training year. Only one teacher specifically negotiated A-level teaching at interview; the others were pleased to be offered it and felt that it accelerated them towards a 'trusted teacher' role. None suggested they required it to be satisfied in their first post. We found a contrasting practice in the two Teach First schools: here, A-level teaching formed a *necessary* part of good early career training. There was a difference in emphasis between these two schools reflecting different approaches found in the literature on career development: protected classroom apprenticeship in one and planned introduction of school responsibilities (Coldwell et al., 2010) in the other. Thus, Pat's department saw A-level as a protective and rich microcosm in which she could get feedback about learning and teaching, and so develop excellence in her classroom practice. Nadiya's department espoused a career development approach that prioritised taking on responsibilities so that all teachers had some input to the administrative leadership of the department and the strategic school vision.

We note that Teach First schools have particular characteristics, including a commitment to developing leadership (so that trainees are viewed as sources of immediate potential) and relatively high turnover of teachers (so that roles need filling). This explains, in part, the finding of these (differently-conceived but) planned and integrated cross-phase inductions. However we also note that it was difficult to find A-level teachers amongst the large Teach First NQT cohort, many of whom have non-specialist backgrounds. In Nadiya's case, but also in Anna's, we see evidence of a protean approach to career where responsibilities such as A-level teaching are sought, used to build personal capacity and then permit a move to another post. This contrasts to David and Pat who give the impression of settling into one post in order to become the kind of teacher they imagine. They are not uncritical apprentices, however, as both have at times seriously questioned the match between their vision of teaching and the possibilities offered in the workplace.

Unsurprisingly, these HoDs and teachers justified early career A-level teaching as having benefits that outweigh any risks. The standard approach of class-sharing was seen to mitigate against any long-lasting adverse consequences for students and, where our teachers reported interventions, HoDs had ready strategies for remedial action. The benefits of A-level teaching identified by beginner teachers were often framed as *complementing* their main school teaching: they included opportunity for an in-depth focus on learners; classes that allow experimentation as

to what works and what doesn't; students that forgive errors while routines become established; flexible opportunities to adapt teaching approaches mid-lesson; appreciating the 'big curriculum picture'. Others were *contrasting*: relief from behaviour management; opportunities to re-engage with mathematics that challenged them; the status of A-level. We discuss below how these benefits were experienced. It is worth noting here that many of these identified benefits arise, as suggested by Butcher (2003), from the affordances of often smaller classes with self-motivated, amenable students and so are not limited to A-level teaching and might be found in other post-16 experiences such as teaching Core Mathematics or perhaps GCSE resit. This raises the question of whether there are any distinct benefits arising from the pedagogic features of A-level mathematics itself. Appreciation of the big curriculum picture, in-depth knowledge of learners and flexibility to adapt teaching approaches may all be influenced by the nature of the mathematics involved.

Support

All the NQTs had the required weekly lesson timetabled for meeting an allocated mentor. All shared a class with an experienced teacher, and all but Anna had access to other teachers who were currently teaching the same material. These induction structures were put in place at the beginning of the NQT year. In addition, three participants were encouraged to take the non-masters TAM course (two in the first year of teaching A-level) and one enrolled herself on TFM.

The availability of support translated into variable practice, with mentor meetings less regular and structured, and dissipating entirely by the end of the NQT year. All but David felt they had been given an initial orientation to A-level in the form of two key messages that echoed through their reflections on what they had learnt distinctively about A-level teaching. We summarise these as: 'year 12s are overgrown year 11s' and 'do all the questions/prepare thoroughly'. Teachers and advisors emphasised the warning that their A-level students, although apparently mature, needed the same engagement and monitoring strategies as younger students. In each case, David's included, and despite the warning, teachers recounted a realisation that they had over-estimated the mathematical knowledge and – even more visibly - the learning skills of their students. They felt an initial disappointment that students, whom they felt to be on their side, had broken an unspoken pedagogic contract. As Butcher (1998) reported, they showed evidence of mis-identifying A-level students with their own self-motivated university selves. As a reaction, and predominantly to get students back on track, teachers reported adopting routines from main school teaching into A-level, some disciplinary and managerial (such as checking every textbook homework) while other routines focussed on tasks and assessment to allow responsive teaching. The TAM resources were among examples of 'reform artefacts' (in the sense of Horn, 2005) used by these teachers to experiment with different routines through which to develop a sense of what freedoms students could be allowed in their activities and what learning benefits they perceived. By the end of the NQT+ 1 year, teachers were still returning to this message and negotiating their own understandings of how to balance respect for students' independence with supportive teaching and performativity demands.

Turning to the second message, although our teachers reported variable time preparing for A-level classes, usually constrained by other priorities, they all agreed on the importance of thorough preparation. They connected it, initially, to the fear of failing to display the MCK that students require from teachers, and the mentors' initial formulation as 'do all the questions' corresponded to advice about reducing uncertainty in the classroom. Although this secured the target content, teachers later broadened their idea of thorough preparation to include establishing knowledge about students' thinking, sometimes asking other teachers for advice. They attached this message to the pedagogical pleasure they experienced when they were able to identify an unexpected line of thinking in the classroom and respond to it. Hence they showed their awareness of using

knowledge to respond to contingencies, an area noted in the literature as fruitful for reflective conversations about PCK (Turner & Rowland, 2011). We also see a significance here for teacher identity: through this message, they identified with pleasure one area where hard work, using their existing mathematical expertise, would secure successful teaching and they contrasted that with the often draining and unpredictable work towards meeting other demands, especially in main school teaching. It was notable how close to failure each of these well-qualified and dedicated young teachers felt.

Outside these key messages, teacher learning about A-level was largely informal and logistical. Only Nadiya reported that formal weekly mentor meetings continued throughout the first year; others felt they were reluctant to claim time from busy colleagues. Some had fairly frequent informal conversations about their shared A-level classes but, looking back on the NQT year, felt these were focused on liaison around organisation and monitoring students. This does not mean these conversations were not valuable at the time: indeed they contributed to establishing the knowledge of local context that McCormack, Gore & Thomas (2006) identify as an early but passing concern of new teachers. We classify them as 'rehearsals' in the learning typology suggested by Horn (2010) of rehearsals, replays and re-envisioning practice; however they focused on overview planning and 'what we do' rather than the purposes of classroom teaching. The key message of overestimating student maturity was one that did inspire reflection with mentors, and some of these conversations (including those with us) included teachers 'replaying' their actions in the classroom and articulating what they had learnt from these. Nadiya was the only teacher to report using a significant part (95%) of her NQT mentor time to rehearse approaches to A-level teaching and seek advice on what students would find difficult. This was not with the other teacher for that class, also her HoD whose concern was to promote her mathematical knowledge: instead their interactions focused on 'doing the questions'. The structured mentor time in that department certainly supported Nadiya through her A-level induction but even she felt that it fell short of allowing her to develop a personal repertoire and (in Horn's terms) 're-envisage' her teaching outside the school's dominant example-then-practice model.

Overall, teachers felt that the initial offers of support largely failed to crystallise into guided reflection on A-level teaching, and that they could have improved their practice more, and more quickly, if A-level teaching had the same profile in staffroom discussions as main school teaching. Teachers were realistic about opportunities missed, but for some (David, Pat, Nadiya) the quality of input they received, or the lack of it, was reported as a significant weakness of the school in contributing to their career development. The PGCE graduates, in particular, noticed that they missed the type of reflective conversation relating practice to the purposes of teaching that they had experienced during their training year. These two, but others also, were effusive about valuing the quality and depth of informed reflection our visits supported, and identified it as supporting their development and their job satisfaction, as well as, in some cases, helping the to resolve in-school issues in a professional way.

It is notable that for the four teachers who participated in TAM or TFM courses, these provided an additional source of subject-specific specialist knowledge, identity-building, and reflection in a professional community beyond the school. For Chris, the sharing of his TAM learning within the department in a structured way evidenced the trust he felt the department was placing in him. Lynch et al. (2016) suggest that such tailored professional development enhances teachers' engagement and so their retention in the profession. All TAM/TFM participants reported the associated Integral resources to be high quality, supporting their informed planning for A-level teaching, contributing to making early career teaching loads manageable, and offering structures and approaches that enhanced their main school teaching and were consistent with their professional values: again, the link with retention is clear.

The effects of teaching A-level in early career

The first effect we note was on these early career teachers' sense of themselves as professionals. The trust conveyed through allocation of A-level made a small contribution. The more significant effect reported was the alignment with their imagined identity as a successful learner-turned-teacher at a time when they were all struggling with the exhaustion, competing demands and frustration of conspicuously failing with routines that experienced teachers rendered invisibly (Berliner, 2004). Teachers compared their A-level teaching to their own experiences as A-level learners and they related it to their previous visions of what ideal teaching would be like: through these reminders they kept in touch with their career aspirations. Re-engaging with challenging mathematics reminded them of the satisfactions of intellectual curiosity and also helped them reflect on the experience of being a learner, and this informed their approach to the content. All our teachers reported moments in A-level teaching where had been able to see, on the spot, how to modify their approach to support learning and talked of these as important in realising that they really were growing as successful teachers.

Secondly, teachers talked about the intensity and quantity of A-level related work, but in ways that varied between teachers and over time. All except Nadiya talked of A-level teaching as providing a vital relief from the intense pressures of managing student behaviour, so that A-level teaching was usually experienced as less stressful than KS3/4. All described occasional moments of intense awkwardness or anxiety, but the likely outcomes of misjudging an A-level class were generally understood as less "drastic". As NQTs, all the teachers except David considered the preparation needed for planning A-level lessons a significant addition to the already heavy workload (Nadiya compared it with taking two extra year 8 classes). David, consistently, and the others at times, tolerated under-preparation for A-level teaching because it received less scrutiny or consequences than other teaching. Chris reported realising he needed to increase his A-level planning as other pressures waned. Marking A-level work was also considered to need more time-consuming pedagogical scrutiny: the nature of the mathematical questions could make it difficult to work out what A-level students were thinking and how to give formative feedback. Smaller classes partly balanced this. The early career teachers framed the workload for A-level as somehow different from that needed for main school teaching and considered it worthwhile, sometimes claiming it as restorative. There are resonances here with the ways that workload is known to affect retention: teachers make a distinction between work that is personally productive/classroom-focussed and work that is used primarily for accountability (Sellen, 2016), and it is the latter that is blamed when they report intending to leave the profession.

The classroom setting

There were two main ways in which we have identified A-level experiences as contributing to these teachers' professional learning. The first is mediated by the mental space and time that is released for them in the classroom by having small, amenable classes in which administrative and behaviour-centred organisation is less intrusive. Teachers spoke of the opportunities to observe students' live attempts at problems, learn what they found difficult and appreciate how mathematical reasoning developed using representations and language that differed from their own preferred approach. All these are developments of PCK concerned with students and mathematical thinking. Several teachers reported with surprise what many of us have found - that their own mathematics improved as a result of engaging with students, and (in our data) noted it particularly in relation to A-level. Following this attention to students' thinking, they articulated an increasing awareness of the limitations of exposition as a sole approach to teaching, evidenced for example in Nadiya's rejection of example-and-practice, and David and Chris's search for conceptual understanding

rather than transmissive "spoon-feeding". In support of these self-reports, we observed them increasingly using tasks that encouraged student discussion and multiple approaches. Although they were not yet always able to exploit all the opportunities of such tasks, these early career teachers used them with the deliberate intent of assessing what knowledge students brought to the lesson and what they made of the teachers' initial explanations, in order to adapt subsequent parts of the lesson. A-level teaching thus provided a space to diagnose and improve their own teaching in vivo.

There was no suggestion that A-level students were, simply by their maturity, any better able to communicate their learning needs. In fact, Nadiya spoke of being challenged by their silences and David of their attempts to hide misunderstandings. Having identified this issue and the potential for learning *from* students about approaches to the mathematics, the teachers used routines and materials they had met in main school teaching (and TAM resources) to encourage student engagement (For example, Anna's final observed lesson showed her building on student talk during a peer assessment exercise to highlight specific messages). In the A-level setting they were better able to perceive the purposes and benefits of these activities for formative assessment. A similar effect of these smaller, amenable classes was the opportunity to develop behavioural routines around group and practical activities. Pat in particular spoke of trying out classroom routines and materials with the A-level group in order to improve her instructions and resource management, establishing expectations for herself rather than the students. Together, these emphases on refining teaching purposefully, creating a desired learning environment and establishing the techniques to organise it smoothly started teachers on the path to building a personal repertoire. Teachers did speak, usually in the NQT+1 year, of getting to know the A-level students as individual young people and learning how to manage their teacher persona within this less formal relationship. This gave them an entry into forming similar nuanced teacher relationships with younger age groups.

Engaging with the mathematics

The second way in which we identified A-level teaching contributing to teacher learning was mediated by teachers' engagement with mathematics. All the teachers spoke of gaining a bigger picture of mathematics through teaching A-level. Their experiences of meeting diverse ways of thinking about A-level mathematics helped them appreciate connections and distinctions between mathematical topics and representations. This gave them confidence in their mathematical knowledge and flexibility in the way they communicated with students. They increasingly expected students to find multiple ways of approaching a problem or articulating their reasoning, because the conceptual density of the content meant they needed these for themselves. Pat, in particular, considered that the A-level syllabus was more connected and coherent than the GCSE syllabus, which meant that she could find ways of differentiating content and building up student knowledge.

Much of this 'bigger picture' thinking was about relationships within school mathematics. Nadiya's use of decision mathematics algorithms as context for year 7 problems, David and Chris's appreciation that year 11s need algebraic fluency, and Pat and Anna's concerns about excessive modelling of examination-focused procedures in KS4 are all concerned with how one aspect of the school curriculum can affect another. As such they show good curricular knowledge but largely fall short of the 'horizon knowledge' envisaged by Hill et al (2008) which encompasses relationships with mathematical ideas, structures, and principles outside school mathematics. There is evidence that this may be difficult for novices to learn (Kuntze et al, 2011).

Nevertheless, in our data, Pat, Anna and David came to set expectations for rigorous reasoning in their A-level teaching and attempted to convey that mathematicians wanted to prove

results in order to understand why they were true. They explicitly linked their valuing of rigour to the mathematical experiences in their degree courses and talked about the suitability of their A-level teaching for progression to university. This was notably different for Nadiya: she achieved the rationale for her A-level induction by gaining a much deeper knowledge of school mathematics, but she did not discuss how this related to the wider discipline nor to her own degree studies. For us this suggests that making connections between A-level teaching and wider mathematics should indeed be considered part of the content knowledge learnt through teaching. Such connections are certainly not guaranteed by knowledge of mathematics but, as proposed more generally by Schmidt et al (2016), teachers' opportunities to learn advanced mathematics do affect the development of their pedagogical knowledge.

The contribution of A-level teaching in early career

Our study has identified developmental opportunities afforded by A-level teaching, but these came at an already stressful career stage. They made distinctive cognitive demands on these teachers, in terms of preparing content and pedagogical content and reflecting for, on, and in teaching (Cochran-Smith & Lytle, 1999), and this resulted in productive mathematics and mathematics pedagogy learning that also contributed to their main school teaching. This preparation, and also the detailed and more cognitively-demanding marking needed, demanded significant additional time commitment, though that was sometimes 'squeezed' by day to day pressures. For most of these beginner teachers, most of the time, these investments were well justified by the ensuing mathematical and professional satisfactions. However, for Nadiya, much more limited subject knowledge at A-level brought considerable *extra* demands on time and effort that were additional to and of a different nature from those made by her main school teaching; they also limited the effectiveness of her A-level teaching.

One question we have considered is whether A-level teaching, while adding demand through its mathematical complexity and depth, is of a fundamentally different nature to earlier teaching. Anna and Chris, consistent with their mentors' talk, both described A-level teaching as a *continuum* with main school teaching, and came to see it as offering fruition of that and also a symbiotic opportunity for professional learning. Anna in this regard contrasted the algorithmic thinking underpinning much of the Decision modules (essentially separate from her thinking about main school teaching) with her brief experience with C1 and C2, where the links with and foundations in main school mathematics were much more obvious. In contrast, David initially framed main school and A-level teaching as quite different, but perceived common goals and routines as he grew in experience. We suggest therefore that distinction is often a question of degree, or density of concept, rather than type. S2 content, for example, comprises a small number of conceptually deep networks of quite complex concepts dependent on core ideas which students are likely to understand in a variety of depths. However, it is also particularly demanding in terms of language precision and subtlety, sometimes with some distance between the mathematics and the expression of a rigorous conclusion. David came to see that as offering opportunity for students to develop in depth the rigour of language he was in his NQT+1 year beginning to value and promote in the range of his teaching.

Finally, we turn to the consequences of A-level teaching for retention. Two years after qualification, two of our teachers have moved to independent schools, one into a sixth-form college and one into education overseas. For these teachers, the experience of A-level teaching has added to their career portfolio and been useful in finding other posts. They have all stayed in the profession and, for all except Nadiya, A-level teaching is a central part of how they see themselves developing professionally. Pat argued strongly that it was only her experiences of A-level classes that kept her in teaching at all, showing her a sustainable teacher identity. There are known

differences between teachers' reported intentions and the number who do leave the profession, but Pat's revitalised enthusiasm once in the post-16 college suggests a direct effect. Similarly, Chris reported that his experience with A-level had in part motivated his move to a more balanced life in what he saw as a less challenging/more academic environment. For the schools who have invested time and taken risks with these young teachers, it might seem frustrating that they do not stay to develop into experts. However we have also seen how these young teachers were largely treated as fully accountable members of staff, under all the same pressures to perform as their more experienced colleagues. They expected an induction that supported their teaching to develop at the same rate at their accountability. For Anna, part of the reason to move was a disappointment with the quality of her induction and no planned provision for her to teach other A-level modules. Paradoxically, David who at times reported extreme frustration with the school's expectations of him, is the only one who has stayed into a further year in a maintained 11-18 school, and only he and Pat remain in the English maintained system.

Summary and Recommendations

1. This study mapped variation in how A-level teaching can develop for well-qualified new teachers, based for their training and induction years in 11-18 schools, and identified where they found support and challenge for improving as teachers. As a result, we conceptualise A-level teaching as complementary to main school teaching and argue that it contributes to the development of teaching repertoires.

2. We found a shared understanding that A-level teaching is a privilege, offered after teachers have shown themselves to be strong in mathematics or confident in teaching, and where responsibility for students can be shared with a more experienced colleague. Early career teachers considered it central to their perception of having arrived as professionals, and A-level opportunities were prominent when choosing a second post.

3. Formal mentor support for NQTs soon reduced and was replaced by informal support conversations with available colleagues. In relation to A-level, support focused on logistics and two key induction messages, and addressed only the immediate concerns/risks faced by new A-level teachers. Teachers regretted the near-absence of reflective conversations focused on A-level pedagogy, which occurred only as a response to perceived deficiencies.

4. Teachers developed some aspects of pedagogic content knowledge from A-level teaching more intensively than in their main school teaching. Smaller amenable classes stimulated and allowed teachers to: focus on feedback from learners; reflect critically on exposition and other approaches to learning; experiment and consolidate routines for management and routines for promoting learning. Engagement with A-level content provoked teachers to: appreciate the 'big curriculum picture' (especially if they were teaching pure mathematics or statistics) and refine teaching goals; consider when and how to introduce rigour; engage with a variety of representations; re-engage as learners; plan and deal flexibly with unusual and unexpected student thinking; differentiate interactions with students, though the depth to which these developed of course varied between teachers.

5. Teaching A-level added to these teachers' workloads during a stressful career stage, and, for some, to their reported anxiety. For this sample, of well-qualified young teachers, the planning demand was mitigated by the relief of a contrasting atmosphere and the satisfaction of professional learning that ensued.

6. For several, teaching materials and approaches introduced in TAM or TFM courses were significant in helping teachers to negotiate the purposes of teaching routines, and manage working in non-procedural ways at this level.

7. A-level teaching impacted on early career teachers' sense of themselves as rounded professionals. A-level teaching was a context that aligned them with their imagined identity as a successful learner-turned-teacher. The focus on pedagogy proved a powerful affective stimulus for sustained effort.

8. For some of these well-qualified teachers, experiences of teaching A-level during early career were critical in retaining them within the education sector.

Recommendations

NCTL and ITE providers should:

- promote the professional satisfactions of teaching A-level in teacher recruitment materials.
- recommend the availability of 11-18 early career experience during training and/or NQT years, where local structures allow. This study suggests A-Level experience can be beneficial for all teachers of mathematics, if suitable support is available.
- note this study adds to evidence of the benefits of more sustained, deeply informed and reflective mentoring of early career teachers – focused across the range of their pedagogical activity.

DfE should:

- continue to support courses such as TAM/TFM, AMTEC that develop specialist mathematics alongside pedagogic knowledge. These provide access to high-quality professional communities and expert-developed resources that support better learning, teacher engagement and retention.
- when re-developing structures for 11-18 provision, be cognisant of the satisfactions, benefits to teaching, and retention impact for 11-16 teachers of also teaching A-level.

School mathematics departments should:

- plan induction and support for post-16 A-Level and Core Mathematics teaching as part of a retention strategy that identifies and builds on early career teachers' mathematics-related developmental needs and aspirations.
- observe NQTs teaching A-level as a focus for developing their knowledge of students, curriculum connections, repertoires for formative assessment, student engagement, flexibility and differentiation.

FMSP should:

- encourage departments and senior leadership to promote and develop level 3 teaching and targeted reflective mentoring, for example as part of school action plans.

Future research should: include longitudinal studies to capture teachers' changing reflections, and whether/how the claims that they make about their teaching are embedded or alter over time. Similar studies are needed to explore the benefits and tensions of teaching A-level for other, less well-equipped early career teachers, or those outside 11-18 schools; and also the parallel affordances and constraints of other post-16 teaching (for example, teaching Core Mathematics, or GCSE resits).

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To reference this report: Smith, C. and Golding, J. (2017). Teaching A-level Mathematics in Early Career: Report for the Further Mathematics Support Programme, London: UCL Institute of Education.

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UCL Institute of Education Supporting Advanced Mathematics Project